Preliminary Observations of the Behavior of *Aplysia dactylomela* (Rang, 1828) in Bimini Waters

BY

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(1 Text figure)

ALTHOUGH APLYSIA HAVE become increasingly important in neurophysiological and biochemical studies because of their large and identifiable neurones (KANDEL & KUPFERMANN, 1970; NEWBY, 1974; ARVANITAKI & CHALZONITIS, 1955; TOEVS & BRACKENBURG, 1969; COGGESHALL, 1970), their ontogeny, behavior and ecological adaptation are not completely known (HYMAN, 1967; EALES, 1921; BEBBINGTON & THOMPSON, 1969; CAREFOOT, 1967; WILLOWS, 1974; JACKLET, 1972; PRESTON & LEE, 1973; KUPFERMANN, 1974; STRUMWASSER, 1971; FRINGS & FRINGS, 1965; TOBACH *et al.*, 1965). We[2] have studied the behavior of *Aplysia dactylomela* (Rang, 1828) in the waters of Bimini, Bahamas during a total of 16 weeks of observation during the period between May, 1964 and April, 1973, in the course of 6 short-term field trips. The Bimini Island group is east of Miami, Florida, on the edge of the Great Bahama Bank. North Bimini, South Bimini and East Bimini define an extensive shallow water lagoon area with frequently occurring sponge and coral bed communities as well as extensive mangrove and thalassia populations (Figure 1) (BATHURST, 1971; HAY *et al.*, 1971; VOSS & VOSS, 1960; and ZAHL, 1952).

The following data were obtained in a series of observations and experiments each of which is individually reported below. The first report is a recapitulation of the data obtained during the years between 1964 and 1973, inclusive.

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DISTRIBUTION AND CONSPECIFIC CONTACT

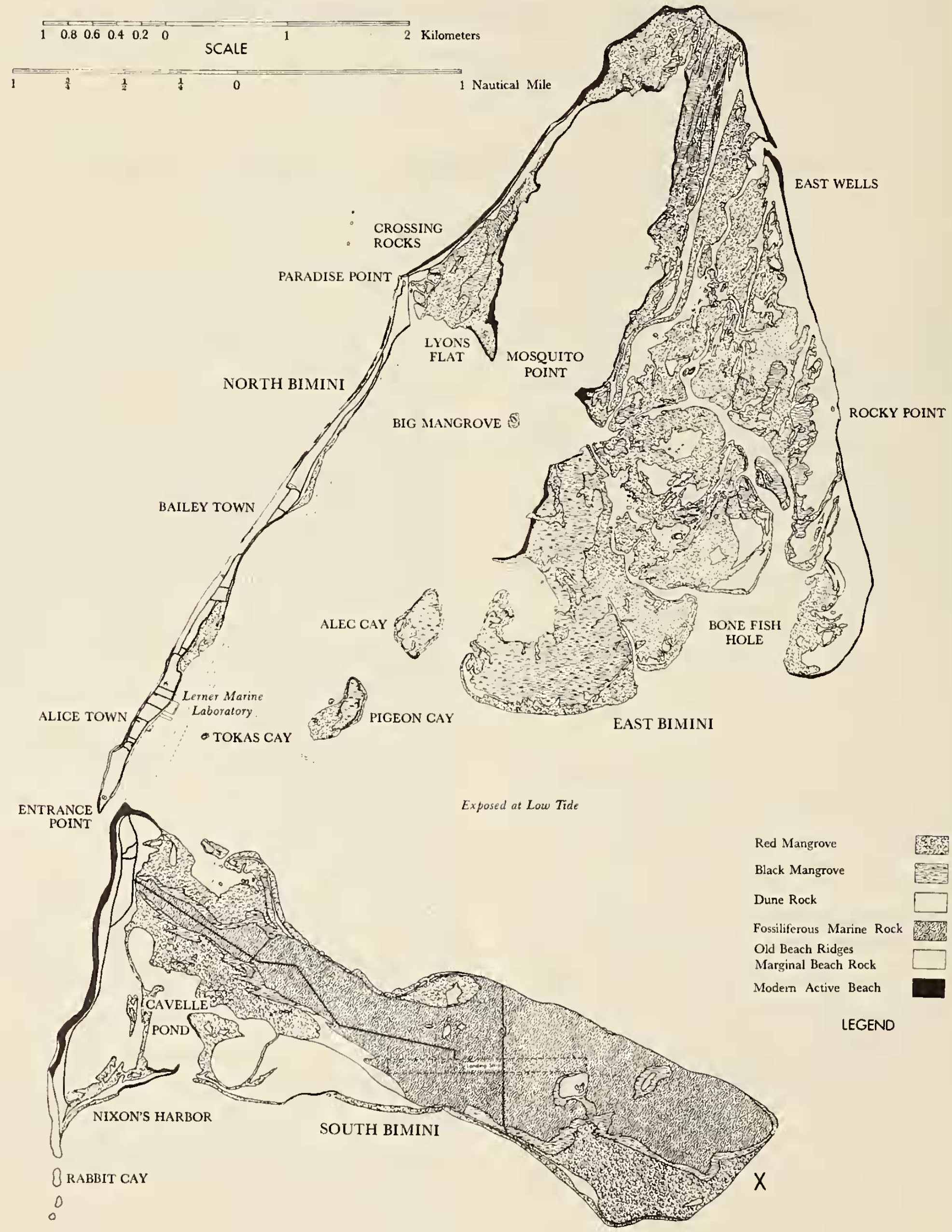
1. Procedures

Our observations were carried out in North Bimini, mainly in Lyons Flats, which is a moderately soft-bottom region bounded by mangrove to the north and a sandbar to the west. To obtain reliable behavioral data, the search for animals, their identification, their stimulation and the recording of their responses were carried out systematically under tidal conditions favorable to such procedures. Thus, observations were carried out during day-light hours, and at depths which only required wading or snorkeling. When a sea hare was found, the time, location, weather and tides were noted. The status of conspecific interactions, that is, contact or copulation, was recorded.

To keep tactile manipulation of the animal to a minimum, the following technique was used routinely. A mesh or plastic bag was drawn between the body and the substrate which had the effect of floating the individual into the bag. The bag could be slipped between the bodies of copulating sea hares. To identify individuals, a tag was secured to one parapodium. The parapodium was held between the thumb and index finger while a stainless steel safety pin, color coded with waterproof tape, was inserted and guided out again by the index finger.

2. Results

Table 1 shows the distribution of animals found individually or in contact according to the months in which we observed them: January (1972); April (1973); May (1964); June (1970, 1972); and July (1968, 1970);



1 0.8 0.6 0.4 0.2 0 1 2 Kilometers
SCALE
1 ¾ ½ ¼ 0 1 Nautical Mile
CROSSING ROCKS
PARADISE POINT
EAST WELLS
LYONS FLAT
MOSQUITO POINT
NORTH BIMINI
BIG MANGROVE
ROCKY POINT
BAILEY TOWN
ALEC CAY
BONE FISH HOLE
Lerner Marine Laboratory
ALICE TOWN
PIGEON CAY
EAST BIMINI
TOKAS CAY
ENTRANCE POINT
Exposed at Low Tide
Red Mangrove
Black Mangrove
Dune Rock
Fossiliferous Marine Rock
Old Beach Ridges
Marginal Beach Rock
Modern Active Beach
LEGEND
CAVELLE POND
NIXON'S HARBOR
SOUTH BIMINI
X
RABBIT CAY

Table 1

Number of *Aplysia dactylomela* Found

	In Contact			Not in Contact			
	Morning	Afternoon	Subtotal	Morning	Afternoon	Subtotal	Total
April, May, June (2[1])	52	24	76	57	148	205	
July (2[2]), January	70	19	89	109	67	176	
Subtotal							
AM	122			166			288
PM		43			215		258
Total:			165			381	546

[1] = 1970 and 1972
[2] = 1968 and 1970

and the time of day. Data were not gathered during the other months of the year. We have tentatively grouped July and January data on the assumption that the beginning and end of the rainy season are represented by these months. Analysis of the data showed no differences between the distributions of January and July according to time of day, or among the other months that were grouped.

In the course of our observations, we found more animals in the morning (288) than in the afternoon (258) and more animals individually (381) than in contact with another animal (165). In addition, distribution of animals not in contact varied according to season, in that the number of animals found individually was greater in the afternoon during the months of April, May, and June (148), but was smaller during July and January (67) $X^2 = 44.86$, $p < 0.001$), whereas the distribution in the morning was in the opposite direction (57 and 109 respectively). Animals found in contact, however, did not vary in number according to time of day during the different seasons.

Comparable tidal data at different times of day were available only for 3 weeks: June 24-30, 1970; June 24-30, 1972; and January 19-25, 1972, which are shown in Table 2. During flood tide conditions, as no animals were found in contact in June, 1972, the differences between that week and the weeks of June, 1970 and January, 1972 are self-evident; the weeks of June, 1970 and January, 1972 are clearly not different from each other. During ebb tide, we found no animals in contact in January, 1972. This is clearly different from our findings in the June weeks.

Analysis of the distributions of animals found individually during flood tide also showed a difference between June, 1970 and June, 1972, in that more animals were found in the afternoon than in the morning in June, 1970 ($X^2 = 9.28$; $p < 0.01$) than in June, 1972. While the morning and afternoon distributions in June, 1970 were different from those in January, 1972 ($X^2 = 37.09$; $p < 0.001$), those of June, 1972 were not different from January, 1972.

Table 2

Number of *Aplysia dactylomela* Found in Relation to Tides

		In Contact		Not in Contact	
		Flood Tide	Ebb Tide	Flood Tide	Ebb Tide
June, 1970	Morning	10	6	4	16
	Afternoon	2	0	23	8
June, 1972	Morning	0	7	12	11
	Afternoon	0	2	11	9
January, 1972	Morning	23	0	36	5
	Afternoon	0	0	4	25

During ebb tide, however, the distribution of animals found not in contact during June, 1970 and June, 1972 were both different from January, 1972 ($X^2 = 15.51$; $p < 0.001$; and $X^2 = 9.69$; $p < 0.01$ respectively).

The morning and afternoon distributions of animals were different during flood and ebb tides during June, 1970 and January, 1972, although in opposite directions ($X^2 = 16.22$ and 40.76 respectively; $p < 0.001$). No differences were found in the June, 1972 distributions.

It seems that time of day, tide, and month are relevant to conspecific interactions in sea hares.

CHANGES IN LOCATION

Activity rhythms have been demonstrated in *Aplysia californica* (Strumwasser, 1966, 1971; Kupfermann, 1968; Jacklet, 1972) and may play a role in night-time feeding in *A. dactylomela* (Carefoot, 1970). Generally, *A. dactylomela* moves by pedal locomotion and taxis, and although the swimming of aplysia has been described (Eales, 1921; Bebbington & Hughes, 1973), we have never observed *A. dactylomela* to change its location either in the field or laboratory by this method. Changes in the distribution of sea hares are probably brought about by any or all of these means of movement, but it is uncertain whether they may also occur through passive displacement because of currents and tides.

Based on our own observations, we think that it is useful to make an assumption, because the lagoon acts as an elevated table land in respect to the ocean, incoming waters rise slowly and outgoing waters fall quickly. We have also observed a predominantly NE and SW flow around Lyons Flats and adjacent areas. As a result, there are consistent changes in the direction and flow to which the sea hares may respond. For further information about the complexity of the water current patterns around the Bimini Island group, see Hay *et al.*, 1971.

The potential effects of these tides on the movements of the animals was demonstrated when we charted the location of a group of animals in Lyons Flats on a daily basis.

1. Procedures (1968)

A group of 36 animals was captured and tagged in South Bimini, transported to Lyons Flats, and placed in a density of 1 per $1\frac{1}{2}\,m^2$. For 12 days, the location of each animal was recorded approximately every 24 hours. During this period, 34 animals were re-located after 1 day. Subsequently, 30 animals were re-located at least once again during the 12 day period. The data were analyzed in terms of the direction of displacement from the original location to the final location at which the animal was found.

2. Results

Of the 34 animals found on the 2[nd] day, 8 were found displaced to the NE, 4 to the NW, 17 to the SE and 5 to the SW. This distribution differed significantly from chance ($X^2 = 12.35$; $p < 0.01$). As it appeared that the movement of the water at flood tide was toward the shore (generally a NW direction), and at ebb tide was away from the shore (generally a SE direction), it was reasonable to analyze the relocation data in terms of movement of the animals in relation to the dominant direction of flow during the period when the animals were in the flats.

Within a 12 or 24 hour period, an animal should experience almost equal amounts of ebb and flood tides. Since our observations could not occur precisely 12 or 24 hours following placement, the sea hares, if pushed or pulled mechanically by the flow of water, should show displacement in the direction in which the water flowed most of the time. Thus, one could determine the "net" action of the tide, in respect to the amount of time between observations. The relationship between the sea hares' displacement and tidal changes are clearly demonstrated in Table 3. A significant bias in the distribution ($X^2 = 9.44$; $p < 0.01$) indicated that the sea hares appeared to be actively changing location in a direction opposite to the movement of the water. These data cover the direction of the animals' movements from their first locations to their last known locations. During the 12 days, the last location of 3 animals could not be categorized in relation to the shore. It should be noted that the net action of the tide between the time on the day of placing the animals in Lyons Flats and the time of their re-location the next

Table 3

Number of *Aplysia dactylomela* Displaced In Relation to Shore In Lyons Flats During Twelve Days (1968)

	Direction of Location Change	
Net Action of Tide	Toward Shore	Away from Shore
Toward Shore	1	15
Away from Shore	9	6

day was toward the shore, yet most of the animals had re-located away from shore (see above, Results section).

An alternative explanation of the direction of the displacement of the animals is that they were moving toward South Bimini, from where they had been transported. During the next field trip (1970) groups of animals were collected from 4 different locations, including South Bimini, tagged, and then released in Lyons Flats. On consecutive days, each group was released in the Flats and on the same day the location of all the animals in the Flats was recorded. In this way, we were able to obtain some measure of the direction of the displacement of the animals daily over a period of 11 days. Table 4 shows the data obtained and suggests that the dominant direction of movement was opposite to the direction of the tide ($X^2 = 5.05$; $p < 0.05$).

In addition, in no case was the predominant movement of any group of animals in the direction towards their original capture point.

Table 4

Number of *Aplysia dactylomela* Which Changed Location (On First Day After Release) During Twelve Days (1970)

	Direction of Location Change	
Major Action of Tide	West	East
East	14	8
West	5	13

INTERSPECIFIC RELATIONSHIPS

The movements of the animal, and thus its reproductive behavior, can also be influenced by interspecific interactions, including predation. Relatively little is known about these interactions (Beondé, 1968; Vicente, 1962; Winkler & Tilton, 1962; Paine, 1963; Scheuer, 1971). We found 2 interspecific relationships: one between sea cucumbers and aplysia and the other between sessile jellyfish and aplysia. In the first instance, we never found great quantities of aplysia in association with populations of sea cucumbers, although occasionally an individual sea cucumber might be found close to, or in contact with, a sea hare. It is known that when under stress or low oxygen tension, *Actinopyga agassizi* releases holothurin, a toxic substance. It seemed possible that this chemical could repel sea hares and thus limit the overlapping of the ranges of the 2 species.

1. Sea hare and sea cucumber interaction

Accordingly, a pilot experiment was conducted in which water from tanks containing individual sea cucumbers or sea hares flowed into other tanks containing individual sea cucumbers or sea hares. Four pairs of tanks were used. In 4 of the tanks donor animals (2 sea cucumbers and 2 sea hares) were stimulated to release holothurin or ink. In 2 of the recipient tanks an individual sea cucumber and an individual sea hare received water from the tanks with the sea hare ink while in 2 other tanks an individual sea cucumber and sea hare received holothurin. In all 8 tanks gambusia were used to assay the presence of holothurin or other toxic substances. The results are shown in Table 5 and indicate a promising problem for further research.

Table 5

Reactions of Sea Hares *(Aplysia dactylomela)* and Sea Cucumbers *(Actinopygia agassizi)* to Substances (Ink and Holothurin) Released by Each through Experimental Stimulation

	Source of Stimulus	
	Sea Hares: Ink	Sea Cucumbers: Holothurin
Sea Hare	[1]	Inked
Sea Cucumber	[1]	Holothurin released[2]
Gambusia	[1]	Died

[1]No apparent effect

[2]The glands of Cuvier were partially eviscerated, a typical indication of the release of holothurin

2. Sea hare and jellyfish interaction

The possible relationship between the sessile jellyfish *Cassiopea xamachana* and *Aplysia dactylomela* was also studied. In the course of field work, a sea hare was observed to withdraw from the perimeter of the jellyfish. The following experiment was conducted to determine whether *A. dactylomela* withdraws from or avoids *Cassiopea.* Twenty-four jellyfish were placed so that they defined a circle 1.20m in diameter. Five *A. dactylomela* were released individually and repeatedly from the center of the circle. Once released, they were able to move in any direction and were certain to encounter a jellyfish. The part of the body which made the initial contact was noted, and withdrawal reactions were recorded. Usually, initial contact was with the head. The frequency of contact and withdrawal responses are shown in Table 6. The

Table 6

Withdrawal Reactions of *Aplysia dactylomela* Following Contact with the Sessile Jellyfish *Cassiopea xamachana*

Animal	Number of Starts	Number of Contacts	Number of Withdrawals
1	4	4	3
2	3	3	0
3	3	2	2
4	4	4	2
5	4	4	4

data suggest that the sea hares do withdraw, possibly in response to nematocysts released by the jellyfish upon tactile stimulation, or to some chemical substance released by the jellyfish, or both.

DISCUSSION

The work reported here is part of an ongoing investigation into the typical life history of *Aplysia dactylomela.*

One of the most difficult aspects of studying the behavior of the sea hare in Bimini appears to be the low predictability of the location of large populations. As our preliminary investigations have indicated, such factors as season, tides, time of day, and interspecific relationships may be critical in affecting changes in the distribution of the animal. Other factors that may be relevant are seasonal variation in food, changes in habitat related to developmental stages (Eales, 1921; Kay, 1964; Carefoot, 1967; Miller, 1962; Usuki, 1970). A comprehensive understanding of the behavioral adaptation of the species depends upon continued observations of the distribution and behavior of sea hares in the field and laboratory along with developmental studies of the animal from egg to adult.

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